Available online at www.sciencedirect.com
ScienceDirect
Animal Feed Science and Technology
141 (2008) 92–103
ANIMAL FEED SCIENCE AND TECHNOLOGY
www.elsevier.com/locate/anifeedsci

Live performance and environmental impact of broiler chickens fed diets varying in amino acids and phytase☆

W.A. Dozier III[a,*], M.T. Kidd[b], A. Corzo[b], P.R. Owens[c], S.L. Branton[a]

[a] *United States Department of Agriculture, Agriculture Research Service, Poultry Research Unit Mississippi State, MS 39762-5367, USA*
[b] *Department of Poultry Science, Mississippi State University Mississippi State, MS 39762, USA*
[c] *United States Department of Agriculture, Agricultural Research Service, Forage and Waste Management Unit, P.O. Box 5367, Mississippi State, MS 39762-5367, USA*

Received 11 July 2006; received in revised form 20 April 2007; accepted 27 April 2007

Abstract

This research examined the effects of decreasing dietary amino acid density (AAD) and potential interactions of AAD and phytase on growth and nitrogen (N) and phosphorus (P) excretion of broiler chickens. In experiment 1, diets were formulated to high (H) or moderate (M) AAD during prestarter (1–7 days), starter (8–19 days), and grower (20–35 days) resulting in the following dietary treatments: HHH, HHM, HMM, and MMM. The HHH feeding regimen improved ($P \leq 0.05$) body weight gain (BWG) and feed conversion (FCR) from 1 to 35 days of age, but increased ($P \leq 0.05$) N content of the excreta by 180 g/kg. In Experiment 2, three diets were fed from 36 to 49 days varying in AAD (H, M, and low, L) with (500 units/kg) or without supplemental phytase. Broilers fed a diet formulated to L AAD had high FCR. Increasing AAD increased ($P \leq 0.05$) N excretion by 0.56 and 0.80 g per bird

Abbreviations: AAD, amino acid density; N, nitrogen; H, high; M, moderate; L, low; BWG, body weight gain; FCR, feed conversion; CP, crude protein; AA, amino acid; Exp, experiment; P, phosphorus; TSAA, total sulfur amino acids; FI, feed intake; DM, dry matter

☆ Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the United States Department of Agriculture.

* Corresponding author. Tel.: +1 662 320 7505; fax: +1 662 320 7589.
E-mail address: bdozier@msa-msstate.ars.usda.gov (W.A. Dozier III).

0377-8401/$ – see front matter. Published by Elsevier B.V.
doi:10.1016/j.anifeedsci.2007.04.012

compared with M and L AAD, respectively. Phytase supplementation reduced ($P \leq 0.05$) P excretion by 0.18 g per bird, but BWG and FCR were not affected. Dietary phytase and AAD did not interact to reduce N excretion. These results indicate that N excretion could be reduced with dietary manipulation, but effects on FCR should be considered.
Published by Elsevier B.V.

Keywords: Amino acid; Broiler; Nitrogen excretion; Phytase

1. Introduction

Ammonia emissions generated from livestock and poultry confinement operations have stimulated awareness in the USA (National Research Council, 2003). Aerial gas emissions not only cause air quality, odor, and environmental concerns to humans (Lacey et al., 2004) but also adversely affect bird performance and health (Wathes, 1998; Miles et al., 2004). Reducing dietary crude protein (CP) has been a strategy to decrease N excretion and ammonia production, but growth performance can be adversely affected if adequate amounts of dietary amino acids (AA) are not provided (Ferguson et al., 1998a,b; Kidd et al., 2001).

It is well established that the young chick responds to H AAD diets optimizing growth performance and meat yield (Kidd et al., 2004; Corzo et al., 2005; Dozier et al., 2006a), but H AAD diets may not be appropriate as broilers approach market weight. Therefore, decreasing dietary AAD late in development should translate to decreased N excretion and ammonia production of the excreta without negatively influencing production efficiency. In previous research, N excretion and ammonia production were decreased in broilers fed low CP diets, but growth performance was adversely affected (Ferguson et al., 1998a,b). Phytase supplementation has been reported to improve amino acid (AA) utilization (Ravindran et al., 1999; Wu et al., 2003). Therefore, N excretion may be also reduced by supplementing diets with phytase.

Experiment (Exp) 1 evaluated growth performance (1–35 days) and N excretion (33–35 days) of broilers fed diets varying in AAD. In Exp 2, potential interactive effects of dietary AAD and phytase supplementation were examined for broiler live performance from 36 to 47 days of age and N and phosphorus (P) excretion (47–49 days).

2. Materials and methods

2.1. Bird husbandry

Two Exp were conducted. In Exp 1, 240 Ross × Ross 708 (Aviagen, Hunstville, AL, USA) 1-day-old male chicks were obtained from a commercial hatchery and randomly distributed in 48 chick battery cages (Petersime Incubator Company, Gettysbury, OH, USA). There were five chicks per cage until 19 days of age and three birds per cage from 20 to 35 days of age. Each cage contained one feeder trough and a water trough. The number of birds per cage was reduced due to size limitations of the cage during the 20–35 day period. In Exp

2, 2300 Ross × Ross 708 broilers were hatched at the USDA-ARS Poultry Research Unit using recommended manufacturer incubation procedures (NatureForm Hatchery Systems, Inc., Jacksonville, FL, USA). Five hundred male chicks were placed into a common environment until 35 days of age. At 36 days of age, 360 male chicks were randomly selected and placed into 72 grower battery cages (Alternative Design Mfg., Siloam Springs, AR, USA) (five birds per cage) until 49 days of age. Each cage was provided with one feeder trough and one nipple waterer. In both Exp, the experimental facility was a solid-sided house with temperature control. Birds were vaccinated at the hatchery for Marek's disease, Newcastle disease, and infectious bronchitis. Temperature was set at 32 °C from 1 to 7 days, 29 °C from 8 to 14 days, 26 °C from 15 to 21 days, 23 °C from 22 to 28 days, 20 °C from 28 to 35 days, and 19 °C from 35 to 49 days. Lighting was continuous with an intensity of 20 lx from 1 to 7 days and then reduced to 5 lx until the end of experimentation.

2.2. Dietary treatments

In Exp 1, diets were formulated to contain either H or M AAD within each phase of growth (Table 1). Critical AA were formulated on a digestible basis. These values were decreased by 100 g/kg to denote the moderate (M) AAD, which is similar to dietary AAD used by broiler integrators in the USA. Prestarter (1–7 days) and starter (8–19 days) diets were provided as crumbles and grower (20 to 35 days) diet as whole pellets. The four dietary treatments were: HHH, HHM, HMM, and MMM.

In Exp 2, broilers were provided common diets until 35 days of age (Table 2). Starter diet was provided as crumbles and subsequent diets as whole pellets. At 36 days, birds were fed diets formulated to contain H, M, or low (L) AAD (total basis) until 49 days of age (Table 2). Amino acid density of the H diet was selected to represent the concentrations used by broiler companies to optimize meat yield. Conversely, the L diet emulated broiler companies intending to use AAD to minimize diet cost. The M diet was intermediate in AAD between H and L diets.

Diets supplemented with or without phytase were formulated to contain 2.5 and 3.5 g/kg available P, respectively. Phytase (Ronozyme® P, DSM Nutritional Products, Inc., Parsippany, NJ, USA) was supplemented in diets from 36 to 49 days at either 0 or 500 phytase units/kg; therefore, resulting in a 3 (AA) × 2 (phytase) factorial treatment arrangement. Pelleting temperature of the finisher diets was 77 °C, a temperature that did not exceed the manufacturer's recommendation for diets supplemented with phytase. Prior to experimentation, H AAD diet was formulated to contain 500 units/kg of supplemental phytase (Ronozyme® P, DSM Nutritional Products, Inc., Parsippany, NJ, USA) the same dietary formulation was used in Exp 2. Ten samples were collected before and after manufacturing and phytase retention was determined as 780 g/kg with a 100 g/kg coefficient of variation. In addition to the diet samples, phytase (Ronozyme® P, DSM Nutritional Products, Inc., Parsippany, NJ, USA) was analysed to contain 5638 phytase units/kg.

2.3. Measurements

In Exp 1, birds and feed were weighed at 1, 7, 19, and 35 days of age and BWG, feed intake (FI), and FCR were determined by replicate. Mortality was recorded daily, but no

Table 1
Ingredient (g/kg) and nutrient composition (g/kg) of experimental diets (as-fed) (Experiment 1)

Age (days)	1 to 7		8 to 19		20 to 35	
Diets	H[a]	M[b]	H[a]	M[b]	H[a]	M[b]
Ground maize	523.0	595.8	548.5	620.5	612.4	674.1
Soybean meal (480 g/kg crude protein)	352.0	290.4	328.0	266.5	268.0	215.7
Poultry meal (660 g/kg crude protein)	50.0	50.0	50.0	50.0	50.0	50.0
Poultry oil	40.5	28.4	40.3	28.4	38.0	27.7
Dicalcium phosphate	13.0	13.4	12.1	12.5	10.9	11.3
Calcium carbonate	9.4	9.6	9.0	9.2	8.5	8.7
Sodium chloride	4.6	4.6	4.6	4.7	4.6	4.6
Premix[c]	3.1	3.3	3.1	3.3	3.1	3.3
DL-Methionine (990 g/kg methionine)	2.58	2.24	2.39	2.05	2.12	1.78
L-Lysine SO_4 (507 g/kg of lysine)	1.78	2.29	2.00	2.72	2.28	2.73
L-Threonine	0.00	0.00	0.00	0.04	0.04	0.07
Nutrient composition						
Calculated						
AME_n (MJ/kg)	12.9	12.9	13.0	13.0	13.2	13.2
Crude protein	226.2	206.5	224.1	204.9	201.3	172.8
Calcium	9.4	9.4	9.0	9.0	8.4	8.4
Available phosphorus	4.7	4.7	4.5	4.5	4.2	4.2
Sodium	2.2	2.2	2.2	2.2	2.2	2.2
Choline (mg/kg)	1550	1550	1500	1500	1400	1400
Analysed						
Lys	13.8	12.8	13.6	12.4	12.3	10.5
Total sulfur amino acids	9.3	8.7	9.3	8.5	8.5	7.5
Thr	8.7	8.0	8.7	7.8	7.7	6.6
Ile	9.2	8.5	9.2	8.2	8.2	6.7
Val	10.4	9.8	10.4	9.4	9.3	7.8
Arg	15.4	13.9	15.3	13.5	13.4	11.1
Leu	17.8	16.5	18.3	16.8	16.3	14.1

[a] Diet characterized as being formulated to high amino acid density concentrations.
[b] Diet characterized as being formulated to moderate amino acid density concentrations. Diets were formulated using digestible amino acid minimums calculated from coefficients taken from Degussa, 2001 to create high and moderate amino acid density.
[c] Premix provided the following per kg of diet: Vitamin A (vitamin A acetate) 7718 IU; cholecalciferol 2200 IU; Vitamin E (source unspecified) 10 IU; menadione, 0.9 mg; B_{12}, 11 μg; choline, 379 mg; riboflavin, 5.0 mg; niacin, 33 mg; D-biotin, 0.06 mg; pyridoxine, 0.9 mg; ethoxyquin, 28 mg; manganese, 55 mg; zinc, 50 mg; iron, 28 mg; copper, 7 mg; iodine, 1 mg; selenium, 0.2 mg. Coccidiostat was included at 0.75 g/kg that provided 60 g/ton of salinomycin. Choline chloride (700 g/kg choline) was included in all diets ranging from 0.03 to 0.29 g/kg.

further information is given elsewhere. At 33 days, a 48 h total excreta collection period was conducted. Representative samples of feed and excreta were frozen and subsequently dried at 65 °C. Dry samples were then ground through a Thomas–Wiley mill (Arthur H. Thomas Company, Philadelphia, PA, USA) equipped with a 1 mm screen to ensure a homogeneous mixture. Nitrogen determination of feed and excreta samples were prepared for analysis by grinding in a stainless steel blade grinder until caking was observed. Nitrogen content was determined on 0.2 g sample using a Combustion N Analyzer (Elementar, Hanau, Germany) using a previously established method (AOAC, 1996). Feed consumption and

Table 2
Ingredient (g/kg) and nutrient composition (g/kg) of diets (as-fed) (Experiment 2)

Age (days)	1 to 17	18 to 35	36 to 49					
			With phytase			Without phytase		
Diets			H[a]	M[b]	L[c]	H[a]	M[b]	L[c]
Ingredient								
Ground maize	607.4	645.4	671.6	722.6	770.0	676.5	727.5	775.0
Soybean meal (480 g/kg crude protein)	283.6	249.3	221.6	179.4	140.3	220.7	178.5	139.4
Poultry oil	22.5	24.5	32.4	22.9	14.2	30.5	21.0	12.3
Poultry meal (660 g/kg crude protein)	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Dicalcium phosphate	13.0	10.5	7.0	7.2	7.5	1.6	1.8	2.1
Calcium carbonate	10.0	9.0	7.5	7.6	7.7	10.6	10.7	10.7
Sodium chloride	4.8	4.6	4.8	4.9	4.9	4.8	4.9	4.9
DL-Methionine	2.46	1.62	1.42	1.54	1.43	1.42	1.54	1.42
L-Lysine HCl (788 g/kg of lysine)	2.33	1.26	0.59	0.79	0.89	0.61	0.81	0.90
Phytase[d]	–	–	–	–	–	0.2	0.2	0.2
Premix[e]	3.9	3.8	3.1	3.1	3.1	3.1	3.1	3.1
Nutrient composition								
Calculated								
AME_n (MJ/kg)	12.9	13.1	13.5	13.5	13.5	13.6	13.6	13.6
Crude protein	225	210	198	182	167	198	182	167
Calcium	9.4	8.4	7.4	7.4	7.4	7.4	7.4	7.4
Available phosphorus	4.7	4.2	2.5	2.5	2.5	3.5	3.5	3.5
Sodium	2.3	2.3	2.2	2.2	2.2	2.2	2.2	2.2
Choline (mg/kg)	1700	1600	1536	1452	1375	1535	1452	1374
Lys	13.6	11.8	10.5	9.5	8.5	10.5	9.5	8.5
Total sulfur amino acids	9.8	8.8	8.3	8.0	7.5	8.3	8.0	7.5
Analysed								
Lys	–	–	10.6	9.8	8.6	10.5	10.0	9.1
Total sulfur amino acids	–	–	7.8	7.9	7.2	8.0	7.6	7.7
Thr	–	–	6.9	6.1	5.5	6.5	6.2	5.6
Ile	–	–	7.1	7.1	6.1	7.6	7.0	6.2
Val	–	–	8.2	8.4	7.4	8.9	8.3	6.2
Arg	–	–	11.9	10.9	9.5	11.6	10.9	9.7
Leu	–	–	15.4	14.9	13.6	15.5	14.7	13.8
Phytase (units/kg)	–	–	528	543	486	27	43	45

[a] Diet characterized as being formulated to high amino acid density concentrations.
[b] Diet characterized as being formulated to moderate amino acid density concentrations.
[c] Diet characterized as being formulated to low amino acid density concentrations.
[d] Phytase (Ronozyme® P, DSM Nutritional Products, Inc., Parsippany, NJ, USA) was included in diets from 36 to 49 days of age.
[e] Vitamin and mineral premix include per kilogram of diet: Vitamin A (vitamin A acetate) 7716 IU; cholecalciferol 2205 IU; Vitamin E (source unspecified) 9.9 mg; menadione, 0.9 mg; B_{12}, 0.01 mg; folic acid, 0.6 μg; choline, 379 mg; D-pantothenic acid, 8.8 mg; riboflavin, 5.0 mg; niacin, 33 mg; thiamine, 1.0 mg; D-biotin, 0.06 mg; pyridoxine, 0.9 mg; ethoyquin, 28 mg; manganese, 55 mg; zinc, 50 mg; iron, 28 mg; copper, 4 mg; iodine, 0.5 mg; selenium, 0.1 mg. Copper and zinc were formulated to contain 0.45 and 0.1 g/kg, respectively. Coccidiostat (Coban 60, Elanco Products, Inc., Indianapolis, IN, USA) was included in starter and grower diets at 0.8 g/kg (90 g of monensin per ton of complete feed). Choline chloride (700 g/kg choline) was included in the starter diet at 0.1 g/kg.

excreta weight during the 48 h collection period were used to calculate N consumption and excretion.

In Exp 2, bird BW and feed were weighed by cage at 35 and 47 days of age. Body weight gain FI, and FCR were determined per replicate pen. Mortality was determined daily. From 47 to 49 days, excreta were collected for 48 h and N determined as previously described. In addition to the N determination, inductively coupled plasma emission spectroscopy was used to analyze feed and excreta samples for P content (United States Environmental Protection Agency, 1985). Feed samples were ground in a stainless steel blade grinder for 30 s. Two grams of ground feed were then digested on a hot plate using 10 mL of 16 M nitric acid, and 5 mL of 12 M perchloric acid. Digestion continued until the temperature arrived at the boiling point of perchloric acid (200 °C). Once digestion was completed, 10 mL of 250 g/kg (v/v) hydrochloric acid were added, and samples were diluted to 100 mL with distilled water for subsequent analysis. Excreta samples were dried at 65 °C for 48 h and ground as noted previously. One gram of excreta per pen was ashed at 550 °C for 4 h (AOAC, 1996). The ash was subsequently dissolved by adding 10 mL of 3 M hydrochloric acid, covered with a watch glass, and boiled for 10 min. The samples were then cooled, diluted, and analysed as previously mentioned (United States Environmental Protection Agency, 1985).

2.4. Statistics

Data were subjected to the analysis of variance procedure in a randomized complete block design (SAS, 2004). Cage was considered the experimental unit and cage location was the blocking factor. When significant differences were detected, means were separated with Tukey's Studentized Range Test. In Exp 2, significant interactions were not observed, thus data are presented as main effects. Statistical significance was considered at $P \leq 0.05$.

3. Results

3.1. Experiment 1

The difference in analysed values for Lys and TSAA between the prestarter and starter periods was small for the H diets (Table 1). Pronounced differences of CP, Lys, and TSAA were noted between H and M diets during the growing period (Table 1). Increasing dietary AAD improved growth performance from 1 to 35 days, but not from 1 to 19 days of age (Table 3). Broilers provided the HHH feeding schedule had higher ($P \leq 0.05$) BWG than bird fed the MMM schedule from 1 to 35 days. Cumulative FCR (1–35 days) was improved ($P \leq 0.05$) with the HHH feeding schedule compared with other experimental feeding schedules. The incidence of mortality was low (4.3%) and not affected ($P > 0.05$) by dietary treatments (data not shown). Dietary AAD altered N content of excreta and absolute N excretion from 33 to 35 days (Table 4). Broilers fed the H AAD diet increased N intake ($P \leq 0.05$), N excreta content ($P \leq 0.05$), and N excretion ($P \leq 0.05$) on a dry matter (DM) basis over birds provided the M diets. When N excretion was expressed relative to N intake, no treatment differences were apparent.

Table 3
Growth responses of male broilers provided diets varying in amino acid concentrations (Experiment 1)

Feeding regimen	BWG[a] (g)	FI[b] (g)	FCR[c]
		1 to 7 days of age	
H[d]	117	118	1.02
M[e]	116	119	1.01
S.E.M. ($n = 24$)	3	4	0.03
		1 to 19 days of age	
HH[dd]	695	818	1.22
HM[de]	664	811	1.27
MM[ee]	664	813	1.25
S.E.M. ($n = 16$)	9	12	0.02
		1 to 35 days of age	
HHH[ddd]	1910a	2798	1.47b
HHM[dde]	1856ab	2857	1.54a
HMM[dee]	1849ab	2865	1.55a
MMM[eee]	1823b	2799	1.54a
S.E.M. ($n = 12$)	24	49	0.02

Mean values within a column with no common letters (ab) are significantly different ($P \leq 0.05$) as a result of Tukey's Studentized Range Test.
[a] BWG, body weight gain per bird.
[b] FI, feed intake per bird.
[c] FCR, feed intake per bird divided by BW gain per bird.
[d] H, high amino acid density diet.
[e] M, moderate amino acid density diet.

3.2. Experiment 2

Crude protein and TSAA were lower than the calculated values, while Lys was in agreement with formulated concentrations (Table 2). Actual concentrations of total P and phytase

Table 4
Nitrogen balance and ammonia of male broilers provided diets varying in amino acid concentrations from 33 to 35 days of age (Experiment 1)

Feeding regimen	Excreta dry matter (g/kg)	Excreta Wt dry basis (kg)	NEC[a] (g/kg)	NC[b] (mg)	NE[c] (mg)	NEP[d] (g/kg)
HHH[eee]	254	0.242	47.2a	9.09a	2.95a	326
HHM[eef]	241	0.275	40.8b	7.62b	2.33b	308
HMM[eff]	255	0.305	42.5ab	7.38b	2.35b	317
MMM[fff]	236	0.332	41.8ab	7.73b	2.52b	328
S.E.M. ($n = 12$)	14	0.040	1.6	0.22	0.10	13

Mean values within a column with no common letters (ab) are significantly different ($P \leq 0.05$) as a result of Tukey's Studentized Range Test.
[a] NEC, nitrogen content of the excreta on a dry matter basis.
[b] NC, nitrogen consumption per bird.
[c] NE, nitrogen excretion per bird.
[d] NEP, nitrogen excretion divided by nitrogen consumption multiplied by 1000.
[e] H, high amino acid density diet.
[f] M, moderate amino acid density diet.

Table 5
Growth responses of male broilers provided diets varying in amino acid concentrations supplemented with and without phytase from 36 to 47 days of age (Experiment 2)

Dietary treatments	BWG[a] (g)	FI[b] (g)	FCR[c]
Amino acid main effects			
HHH[ddd]	1067	2118b	2.01b
HHM[dde]	1135	2288a	2.02b
HHL[ddf]	1083	2344a	2.19a
S.E.M. ($n=24$)	25	32	0.03
Phytase main effects			
Control	1089	2224	2.06
Phytase supplementation	1103	2277	2.08
S.E.M. ($n=36$)	20	27	0.03

Mean values within a column with no common letters (ab) are significantly different ($P \leq 0.05$) as a result of Tukey's Studentized Range Test.

[a] BWG, body weight gain per bird.
[b] FI, feed intake per bird.
[c] FCR, feed conversion corrected for mortality.
[d] H, high amino acid density diet.
[e] M, Moderate amino acid density diet.
[f] L, Low amino acid density diet.

were in close agreement with calculated values (Table 2). Increasing dietary AAD improved FCR from 36 to 47 days (Table 5). Birds fed the H diet had lower ($P \leq 0.05$) FI than M and L fed birds, whereas the L fed birds had poorer ($P \leq 0.05$) FCR than H and M fed birds. Mortality was low (1.7%) and was similar ($P > 0.05$) among treatments (data not shown). Dietary phytase addition did not alter BWG, FCR, or the incidence of mortality.

Broilers fed the H diet had increased ($P \leq 0.05$) N consumption, N excreta content, and N excretion on a DM basis (Table 6). Nitrogen excretion relative to N intake was increased ($P \leq 0.05$) with birds fed the H diet compared with broilers provided the L diet. Decreasing dietary AAD (L) increased ($P \leq 0.05$) absolute P excretion compared with birds provided M and H diets. Phosphorus excretion relative to P intake was increased ($P \leq 0.05$) by feeding the L diet compared with the H diet. Excreta DM and excreta DM weight were not influenced by dietary AA concentrations. Phytase supplementation increased ($P \leq 0.05$) excreta weight and N excretion, but decreased ($P \leq 0.05$) P intake and P excretion. Excreta DM was not affected by adding phytase.

4. Discussion

The use of H AAD diets throughout production have been reported to improve broiler BWG and FCR (Dozier and Moran, 2001; Kidd et al., 2004; Corzo et al., 2005). The present research observed differences in broiler growth from 1 to 35 days of age, but not from 1 to 19 days of age. Kidd et al. (2005) reported improvements in FCR at 5, 14, and 35 days of age and BWG differences at 14 and 35 days of age with broilers fed H AAD diets compared with M AAD diets. The lack of response to dietary AAD at earlier ages in the present study

Table 6
Nitrogen and phosphorus balance of male broilers provided diets varying in amino acid concentrations supplemented with and without phytase from 47 to 49 days of age (Experiment 2)

Dietary treatments	Excreta dry matter (g/kg)	Excreta Wt dry basis (g)	NEC[a] (g/kg)	NC[b] (g)	NE[c] (g)	NEP[d] (g/kg)	PC[e] (g)	PE[f] (g)	PEP[g] (g/kg)
Amino acid main effects									
HHH[hhh]	229	68	63.3a	10.9a	4.3a	395a	1.74	0.77b	445b
HHM[hhi]	231	64	58.6b	10.0b	3.7b	372ab	1.66	0.79ab	478ab
HHL[hhj]	242	65	54.1c	9.8b	3.5b	353b	1.71	0.88a	511a
S.E.M. ($n=24$)	6	2	1.2	0.2	0.1	12	0.03	0.03	16
Phytase main effects									
Control	240	63b	59.4	10.2	3.6b	355b	1.88a	0.92a	497
Phytase supplementation	227	68a	57.9	10.3	4.0a	391a	1.53b	0.70b	459
S.E.M. ($n=36$)	5	2	1.0	0.1	0.1	10	0.03	0.02	13

Mean values within a column with no common letters (ab) are significantly different ($P \leq 0.05$) as a result of Tukey's Studentized Range Test.

[a] NEC, nitrogen content of the excreta on a dry matter basis.
[b] NC, nitrogen consumption per bird.
[c] NE, nitrogen excretion per bird.
[d] NEP, nitrogen excretion divided by nitrogen consumption multiplied by 1000.
[e] PC, phosphorus consumption per bird.
[f] PE, phosphorus excretion per bird.
[g] PEP, phosphorus excretion divided by phosphorus consumption multiplied by 1000.
[h] H, high amino acid density diet.
[i] M, moderate amino acid density diet.
[j] L, low amino acid density diet.

is in disagreement with previous research (Dozier and Moran, 2001; Dozier et al., 2006a; Kidd et al., 2004, 2005; Corzo et al., 2005) and an explanation for the difference in response between current and previous research is not apparent.

Previous research has found no differences in BWG with broilers fed diets varying in AAD from 5 to 8 weeks of age (Kidd et al., 2005; Dozier et al., 2006b). In the present research, reducing dietary AAD from H or M to L diet during 36–47 days of age increased FCR, but BWG was unaffected. Feed intake was increased as dietary AAD decreased from H to M and L. Broilers fed L AAD diets have been reported to increase FI during the early growth phase (Dozier and Moran, 2001; Kidd et al., 2004, 2005) and late growth period (Dozier et al., 2006b). Increasing dietary AAD may decrease FI by creating an AA imbalance (Acar et al., 2001). In contrast to Exp 2, no differences were observed with FI in Exp 1. Diets were formulated on a digestible basis and had a balanced AA profile in Exp 1, whereas diets used in Exp 2 were formulated on a total basis, which may partially explain differences in FI due to dietary AAD between Exp.

Broilers fed diets containing 20 g/kg CP lower have resulted in 160 g/kg less litter N than the control fed birds (Ferguson et al., 1998a,b). Kidd et al. (2001) also found 80 g/kg reduction in litter N with a 10 g/kg reduction in dietary CP. In Exp 1 of the present study, N content of the excreta and N excretion were decreased 130 and 160 g/kg, respectively, as dietary CP concentration was reduced from 200 to 170 g/kg. Nitrogen excretion was reduced 160 g/kg as dietary CP decreased from 198 to 182 g/kg in Exp 2. Nitrogen excretion was reduced by 30 g/kg in Exp 2 with 16 g/kg lower CP diet. This infers that dietary CP and AA needs were probably lower than the H AAD diet provided in Exp 2. When dietary CP was reduced 30 g/kg, 160 g/kg reduction of N excretion occurred in Exp 1. These broilers were younger than the birds used in Exp 2 and had a higher dietary AA need (National Research Council, 1994). In addition, these diets were formulated on a digestible basis, whereas diets used in Exp 2 were formulated on a total basis.

Methionine is the first limiting amino acid for broiler chickens (National Research Council, 1994). Dietary TSSA requirements for broiler chickens from 0 to 3, 3 to 6, and 6 to 8 weeks of age are reported as 9.0, 7.2 and 6.0 g/kg, respectively (National Research Council, 1994). Total sulfur amino acids for the M diets in Exp 1 were below National Research Council (1994) TSAA recommendations from 0 to 19 days of age but were adequate from 20 to 35 days of age. In Exp 2, the diets had analysed values for TSAA in excess of 7.2 g/kg from 36 to 49 days of age. The small difference in TSAA concentration between the H and M diets may have allowed for good feed conversion yet allowing for decreasing N excretion via a 16 g/kg reduction in dietary CP.

Phytase supplementation of maize and soybean meal based diets has been reported to improve BWG and FCR (Biehl and Baker, 1997; Sebastian et al., 1997; Wu et al., 2003), although contrasting data exist (Ibrahim et al., 1999; Waldroup et al., 2000; Yan et al., 2003). The requirement of available P for broilers beyond 6 weeks of age is lower for growth performance than tibia ash (Waldroup et al., 2000; Yan et al., 2003). In Exp 2, the available P need for BWG may have been at or below 2.5 g/kg of broilers from 36 to 49 days of age (Yan et al., 2003). Phytase supplementation resulted in a marked reduction in P excretion has been documented in previous research (Ferguson et al., 1998b; Ibrahim et al., 1999).

5. Conclusion

Decreasing amino acid density reduced nitrogen excretion but adversely affected feed conversion. Determining an optimum amino acid density to minimize nitrogen excretion must be balanced with poor feed conversion. Phytase supplementation did not further reduce nitrogen excretion when included in diets formulated to low amino acid density.

References

Acar, N., Patterson, P.H., Barbato, G.F., 2001. Appetite suppressant activity of supplemental dietary amino acids and subsequent compensatory growth of broilers. Poult. Sci. 80, 1215–1222.

AOAC, 1996. Official Methods of Analysis of AOAC International, sixteenth ed. AOAC International, Gathersburg, MD, USA.

Biehl, R.R., Baker, D.H., 1997. Microbial phytase improves amino acid utilization in young chicks fed diets based on soybean meal but not diets based on peanut meal. Poult. Sci. 76, 355–360.

Corzo, A., Kidd, M.T., Burnham, D.J., Branton, S.L., Gonzalez-Esquerra, R., 2005. Dietary amino acid density effects on growth and carcass of broilers differing in strain cross and sex. J. Appl. Poult. Res. 14, 1–9.

Degussa, 2001. Amino Dat®2.0. Degussa AG Feed Additives, Hanau, Germany.

Dozier III, W.A., Moran Jr., E.T., 2001. Response of early- and late-developing broilers to nutritionally adequate and restrictive feeding regimens during the summer. J. Appl. Poult. Res. 10, 92–98.

Dozier III, W.A., Gordon, R.W., Anderson, J., Kidd, M.T., Corzo, A., Branton, S.L., 2006a. Growth, meat yield, and economic responses of broilers provided three- and four-phase regimens formulated to moderate and high nutrient density during a 56 day production period. J. Appl. Poult. Res. 15, 312–325.

Dozier III, W.A., Kidd, M.T., Corzo, A., Anderson, J., Branton, S.L., 2006b. Growth, meat yield, and economic responses of Ross × Ross 708 broilers provided diets varying in amino acid density from 36 to 59 days of age. J. Appl. Poult. Res. 15, 367–382.

Ferguson, N.S., Gates, R.S., Taraba, J.L., Cantor, A.H., Pescatore, A.J., Ford, M.J., Burnham, D.J., 1998a. The effect of dietary crude protein on growth, ammonia concentration, and litter composition of broilers. Poult. Sci. 77, 1481–1487.

Ferguson, N.S., Gates, R.S., Taraba, J.L., Cantor, A.H., Pescatore, A.J., Ford, M.J., Burnham, D.J., 1998b. The effect of dietary protein and phosphorus on ammonia concentration and litter composition in broilers. Poult. Sci. 77, 1085–1093.

Ibrahim, S., Jacob, J.P., Blair, R., 1999. Phytase supplementation to reduce phosphorus excretion of broilers. J. Appl. Poult. Res. 8, 414–425.

Kidd, M.T., Gerard, P.D., Heger, J., Kerr, B.J., Rowe, D., Sistani, K., Burnham, D.J., 2001. Threonine and crude protein responses in broiler chicks. Anim. Feed Sci. Technol. 94, 57–64.

Kidd, M.T., McDaniel, C.D., Branton, S.L., Miller, E.R., Boren, B.B., Fancher, B.I., 2004. Increasing amino acid density improves live performance and carcass yield of commercial broilers. J. Appl. Poult. Res. 13, 593–604.

Kidd, M.T., Corzo, A., Hoehler, D., Miller, E.R., Dozier III, W.A., 2005. Broiler responsiveness (Ross × 708) to diets varying in amino acid density. Poult. Sci. 84, 1389–1396.

Lacey, R.E., Mukhtar, S., Carey, J.B., Ullman, J.L., 2004. A review of literature concerning odors, ammonia, and dust from broiler production facilities: 1 Odor concentrations and emissions. J. Appl. Poult. Res. 13, 500–508.

Miles, D.M., Branton, S.L., Lott, B.D., 2004. Atmospheric ammonia is detrimental to the performance of modern commercial broilers. Poult. Sci. 83, 1650–1654.

National Research Council, 1994. Nutrient Requirements of Poultry, ninth ed. National Academy Press, Washinton, DC.

National Research Council, 2003. Air Emissions From Animal Feeding Operations. The National Academies Press, Washington, D.C.

Ravindran, V., Cabahug, S., Ravindran, G., Bryden, W.L., 1999. Influence of microbial phytase on apparent ileal amino acid digestibility of feedstuffs for broilers. Poult. Sci. 78, 699–706.

SAS, 2004. SAS User's Guide. Statistics. Version 9.1 ed. SAS Institute Inc., Cary, NC.

Sebastian, S., Touchburn, S.P., Chavez, E.R., Lague, P.C., 1997. Apparent digestibility of protein and amino acid in broiler chickens fed a corn-soybean meal diet supplemented with microbial phytase. Poult. Sci. 76, 1760–1769.

United States Environmental Protection Agency, 1985. Method 2007. Determination of methods and trace elements in water and waste by inductively coupled plasma-atomic emission spectroscopy. EPA-600/S4-85/05. National Technical Information Service, Springfield, VA.

Waldroup, P.W., Kersey, J.H., Saleh, E.A., Fritts, C.A., Yan, F., Stilborn, H.L., Crum Jr., R.C., Rayboy, V., 2000. Nonphytate phosphorus requirement and phosphorus excretion of broiler chicks fed diets composed of normal or high available phosphate corn with and without microbial phytase. Poult. Sci. 79, 1451–1459.

Wathes, C.M., 1998. Aerial of emissions from poultry production. World's Poult. Sci. J. 54, 241–251.

Wu, Y.B., Ravindran, V., Hendriks, W.H., 2003. Effects of microbial phytase, produced by solid-state fermentation, on the performance and nutrient utilization of broilers fed maize- and wheat-based diets. Br. Poult. Sci. 44, 710–718.

Yan, F., Kersey, J.H., Fritts, C.A., Waldroup, P.W., 2003. Phosphorus requirements of broiler chicks 6 to 9 weeks of age as influenced by phytase supplementation. Poult. Sci. 82, 294–300.